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SALINE AND FLOOD TOLERANT ORGANIC RED RICE VARIETY (*ORYZA SATIVA* L.) FROM KERALA

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Abstract: Sea coastal tracts often faces combined menace of salinity and flood. Breeding for salt stress tolerance is a more promising, energy efficient, economic and socially acceptable approach compared to any other development approach. Varieties having traits amenable for organic farming (organic varieties) are the missing link in the organic production chain. Here we report development and commercial release of a red kernelled organic rice variety christened as 'Mithila' which is tolerant to salinity and suited to sea coastal ecosystem as well as non saline flooded tract. The variety was developed by adopting the combined strategy of conventional breeding linked with novel strategies of organic plant breeding and participatory plant breeding and growing the entire filial generations and all yield trials in the target area. The variety was commercially released in the state of Kerala in 2020.

Keywords: rice, abiotic stress, salinity and flood tolerance, naturally organic tract

INTRODUCTION

It is estimated that half of the world's farms have been damaged by salt (Pearse, F.1987). Breeding for salt tolerance is a more promising, energy efficient, economic and socially acceptable approach than major engineering processes and soil amelioration, which had gone beyond the reach of marginal farmers. In spite of a significant amount of research on the effect of salinity on plants, there has been little success in putting salt resistant plants in farmers' field (Flowers & Yeo, 1995). As the global climate changes makes difference in the microclimate environment, the adaptation and mitigation strategy should be for development of location specific varieties. To attain this, the breeder should utilize locally adapted genetic resources in breeding programmes.

The focus of the present era is upon organic farming for health as well as environment protection. As organic farming management and environments are fundamentally different from conventional, organic farmers need specific varieties that are adapted to their lower input farming system and can perform higher yield stability than conventional varieties (Lammerts van Bueren *et al*., 2003). Many breeding programs took yield potential as the primary target. With the increased living standard, the improvement in cooking, eating, and appearance quality of the rice grain has become a priority. For further optimization of organic product quality and yield stability, new varieties are required that are adapted to organic farming systems (Lammerts van Bueren *et al*., 2003). At this context, development of rice varieties responding well to organic cultural management with good cooking and nutritive qualities and having resistance to important pests and diseases is imperative to meet increasing requirements, in both quantity and quality, and should be in harmony with the environment thus ensuring a proper level of sustainability.

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A challenging breeding project for development of saline tolerant high yielding non lodging variety was begun in 2001 for the first time utilizing a local saline tolerant land race of sea coastal tract *Kaipad of North Kerala* in breeding programme. As a result of sustained research efforts, an array of promising breeding lines were developed, "Mithila' variety one among them was released in 2020 for saline flooded tracts as well as for non saline tracts of Kerala.

MATERIALS AND METHODS

A combined strategy of pedigree breeding, organic plant breeding (Bueren, 2003) and farmer participatory breeding approach (Morris and Bellon, 2004) was followed during the variety development programme. Orkayama, the land race of Kaipad tract of North Kerala ,the newly identified genetic resource for salinity tolerance, biotic stress tolerance, excellent cooking and nutritive qualities and not exploited so far in breeding programmes (Vanaja and Mammootty, 2010) was utilized as donor parent for salinity tolerance. The entire experiment was directly conducted at the target area of saline sea coastal problem area to harvest the genetic potential under field condition. 'Orkayama', the land race was hybridized with high yielding saline susceptible variety , 'Jaya' , in 2001 'which is under cultivation at the proximity of *Kaipad* field. All the filial generations as per pedigree breeding, and yield trials were raised as on-farm trials in the *Kaipad* fields under the test name culture JO 583, ensuring the participation of farmers in the selection process of promising progenies from the segregating filial generations itself as per strategies of participatory plant breeding. The F_2 filial generation was raised in the field adjacent to the saline problem area having intruded slight salinity (2dS m^{-1}), and adopted organic rice farming practices. Single plant pedigree selection was followed in F_2 generation. All the F_2 progenies survived in the slight saline condition were carried forward to F_3 generation in the problem area of *Kaipad,* the target site. From F_3 generation onwards, all advanced filial generations were evaluated directly in the target area having medium salinity. Fourteen high yielding stabilized rice cultures were obtained from thousands of F_2 progenies developed from various cross combinations among saline susceptible high yielding varieties and saline tolerant traditional land races. These promising progenies were evaluated in replicated yield trials in saline *Kaipad* fields along with local lodging check (Kuthiru) and non-lodging *Pokkali* check (Vytilla 6). *Pokkali* tract in Kerala is similar to *Kaipad* tract but differ in soil structure and rice genotypes cultivated. The design of yield trials was RBD with three replications. Salinity level varied between 4 to 8 dS m^{-1}during the cropping season. Culture JO 583 was also tested at 16 locations of different states of India through the National Saline Alkaline Screening Nursery (NSASN) of the All India Coordinated Rice Improvement Programme. Trials were also conducted at saline and flood prone areas of Kerala. Pests and disease scoring was done under natural saline field condition of *Kaipad* and also under artificial infection in non-saline wet land condition of Regional Agricultural Research Station, Pattambi, Kerala, India. Standard evaluation system for rice (IRRI, 1988) was used for describing the cultures.

Participatory Plant Breeding (PPB) is the latest strategy in the area of plant breeding to integrate end user based participatory approach (Morris and Bellon, 2004). It is based on a set of methods that involve close farmer –researcher collaboration to bring about plant genetic improvement within a crop. It is expected to produce more benefits than the traditional global breeding model in situations where a highly centralized approach is inappropriate. Participatory plant breeding methods designed to incorporate the perspective of farmers usually by inviting farmers to participate in selection within the unfinished segregating material with high degree of genetic variability. The efficiency of breeding for salt tolerance was perceived to be low because of the evident genetic complexity of the trait, large genotype x environment interactions, and the problem of controlling relevant environmental variables during field based selection (Flowers and Yeo, 1995). Hence, in order to improve the suitability of the varieties produced to specific local farming situations, the new approach of

farmer participatory varietal selection (Bennet and Khush, 2003) was integrated to develop high yielding varieties suited for *Kaipad* rice field. Realizing the fact that modern varieties developed for favorable production conditions have not always diffused readily into marginal environments, the procedures like selection of parents and segregating progenies were done in the target area of farmers. Further, participation of farmers is imperative when crops are grown in agriculturally difficult and environmentally challenging situations. By involving farmers in the genetic improvement process, plant breeding programmes will be able to produce better varieties that will be adopted more widely and generate greater benefits on aggregate. PPB provides a means of assessing so-called 'subjective traits'. In food crops these include taste, aroma, appearance, texture, and other characteristics that determine the suitability of a particular variety for culinary use. These traits are difficult to measure quantitatively because they are a function of human perceptions.

RESULTS AND DISCUSSION

Varietal diversity with broad genetic base is required in *Kaipad* saline tracts because the tract is highly heterogeneous with respect to salinity for which varieties of different resistance mechanism are essential. Varietal difference in stress resistance is mainly due to difference in regulatory pathway which in turn is under the control of stress induced signal transduction. Hence varietal diversity in an abiotic stress prone area is a must. Heterogeneous breeding populations have to be developed in situations where agriculture is risk prone, complex and require low input like *Kaipad* tract. Varietal diversity is also required to fight against break down of pest and disease resistance. Further, to outweigh the negative impact of micro-climate change and to help mitigate risk in agriculture sector, crop varietal diversity to a particular micro climate is imperative. Carbon dioxide locking capacity of varieties may vary (Flowers and Yeo,1995).

Sustained research efforts adopting new frontiers of crop improvement resulted in development of an array of high yielding saline tolerant rice cultures, having distinct traits, for the first time to the unique sea coastal saline organic rice tracts of north Kerala , *Kaipad* (Vanaja *et al* 2009). These diverse rice cultures were also tested in various trials in saline *Kaipad* ecosystem, saline screening trials of AICRP and also in non saline flooded wetlands of North Kerala.

The details of performance of Culture JO 583 which was released in the name 'MITHILA' for commercial cultivation in Kerala state of India in 2020 are summarized below.

Grain yield

Preliminary Evaluation trial was conducted separately for both non-lodging and lodging genotypes developed as a result of hybridization. Pedigree of selected saline tolerant *Kaipad* rice cultures and their grain yield in PYT, CYT, and farm trials in saline *Kaipad* fields of farmers are given in table 1. Comparative evaluation trial was conducted for good performing non-lodging and lodging genotypes together. In comparative yield trials, five non-lodging cultures, namely, JK 70, JO 345, MK 22, JO 532-1 and JO 583, and one lodging culture, JK 59 showed on par yield performance and significantly higher yield than that of *Kaipad* and *Pokkali* local checks. These cultures have wide genetic base because, one of the parents is a local cultivar having abiotic and biotic stress resistance. These cultures have more grain and straw yield, and higher harvest index than that of local land races. These hybrid derivatives are tolerant to all kinds of pests and diseases at *Kaipad* field condition. Screening in ordinary wetland condition they were invariably found to be resistant and moderately resistant to many pests and diseases. Besides their proven yield potential, pest and disease resistance and other preferable traits to saline and flooded areas, they possess desirable grain qualities as per the farmers need, like absence of awn and non-shattering unlike local land races, better taste and more acceptable appearance of cooked rice, appealing to both consumers and millers. The cooking qualities of all the cultures are above or on par with traditional land race 'Kuthiru' whose cooking qualities are much appreciated by farmers. Out of these cultures, Culture JK 70 was released as 'Ezhome -1' and Culture JO 345

as 'Ezhome -2' in 2010 (Vanaja *et al*., 2015 & 2017). In 2013 Culture MK 22 was released as 'Ezhome -3'(Vanaja *et al* 2015) and in 2015, culture JO 532-1 was released as 'Ezhome -4' (Vanaja *et al* 2018).

The mean grain and straw yield of 'Mithila'(Culture JO 583) in farm trials in *Kaipad* tracts during *Kharif* seasons are given in table 2. Culture JO 583showed 226% more yield than the local check variety. The yield performance of 'Mithila'in National Saline Alkaline Screening trials of AICRP is given in table 3. In alkaline normal soils, coastal saline soils,costal saline normal soils and in inland saline soils of various states of India, compared to coastal check(CST 7-1), 'Mithila"(Culture Jo 583) showed higher yield performance.

Table 1: Saline tolerant *Kaipad* rice cultures in PYTs and CYTs in farmer's field

Sl. No.	*Genotypes*	*Parentage*	*Pooled PYT Grain yield (t /ha)*	*Pooled CYT Grain yield (t /ha)*
1	**Non-lodging genotypes** MK 22(Ezhome-3)	Mahsuri x Kuthiru*	6.61 [a]	5.69 [a]
2	MK 146	- do-	2.26	-
3	MK 162	- do-	1.08	-
4	JK 23	Jaya x Kuthiru	0.99	-
5	OK 43	*Orkayama x Kuthiru	5.73 [a a]	-
6	JK 67	Jaya x Kuthiru	1.11	-
7	JO 560-2-1	Jaya x Orkayama	1.08	-
8	JK 74	Jaya x Kuthiru	6.08 [a a]	-
9	JO 583	Jaya x Orkayama	7.30 [a]	4.70 [a]
10	JK 76	Jaya x Kuthiru	4.88	-
11	JK 70(Ezhome-1)	- do-	7.54 [a]	6.0 [a]
12	JO 532-1	Jaya x Orkayama	6.89 [a]	6.23 [a]
13	JO 556	- do-	1.33	-
14	JO 345(Ezhome-2)	- do-	7.20 [a]	5.86 [a]
15	Vytilla 6	Non-lodging *Pokkali* check	1.91	2.58
	C D (1%)		0.93	-
16	**Lodging genotypes** JK 46	Jaya x Kuthiru	3.20	-
17	JK 59	- do-	4.71 [a a]	4.9 [a]
18	KO 5	Kuthiru x Orkayama	1.35	-
19	JK 15	Jaya x Kuthiru	7.33 [a]	4.0
20	KO 43	Kuthiru x Orkayama	1.68	-
21	JO 32-2	Jaya x Orkayama	1.03	-
22	OK 45	Orkayama x Kuthiru	3.23	-
23	MK 61-1	Mahsuri x Kuthiru	4.70 [a a]	-
24	JO 91	Jaya x Orkayama	3.08	-
25	OK 38	Orkayama x Kuthiru	4.97 [a a]	-
26	JK 58-1	Jaya x Kuthiru	1.05	-
27	JK 58-2	- do-	1.30	-
28	Vytilla -1	lodging *Pokkali* check	2.01	-
29	Kuthiru	Lodging local check of Kaipad	2.10	2.10
	C D (1%)		0.72	2.05

* Land races of *Kaipad* ecosystem

[a] -In a column, means followed by the same alphabet do not differ significantly from each other

PYT: Preliminary Yield Trial CYT: Comparative Yield Trial

Physico-chemical and Cooking qualities

Milling and head rice recovery percentages of 'Mithila' variety are 81.8% and 73% compared to 69.7 % and 68.9% of the local check 'Kuthiru' . As quality is more important in organic agriculture, the cooking qualities of the variety was evaluated in detail. Sensory evaluation for cooking qualities showed that 'Mithila' possess better taste and more acceptable appearance of cooked rice appealing to both consumers and millers. When the sensory evaluation score for taste, flavour, appearance and over all performance of the traditional land race 'Kuthiru' which is very much appreciated by the *Kaipad* farmers long before are 5.9, 4.1, 5.4 and 5.6 respectively, the score for the same for 'Mithila' is more (6.03, 4.4, 5.9 and 6.2). Cooked rice of ' Mithila' is delicious and non-sticky like 'Kuthiru'. Cooked rice is swollen and tender unlike the split and hard nature of that of 'Kuthiru'. Kernel is brown in colour. Nutritive quality evaluation revealed that it has comparatively high content of Ca, Mg and protein. it possess desirable grain qualities like awn-less, fair shattering and medium bold grains unlike awned, shattering and bold grains of traditional landraces.

Pest and disease resistance

There is no incidence of pests and diseases in saline *Kaipad* ecosystem, may be due to high potassium content of soil and salinity induced biotic stress tolerance. Further, when screened

Table 2: Mean grain yield and straw yield of culture JO 583 in Multi location/farm trials during *Kharif* seasons pooled over 27 locations in 6 years

Name of culture/variety	*Mean Grain yield (t/ha) (Mean straw yield t/ha)*							
	2010	*2011*	*2012*	*2013*		*2016*	*2017*	*Pooled Mean*
Culture JO 583	4.7 (11.6)	3.8 (9.2)	4.7 (10.5)	4.6 (7.5)		5.05	5.89	5.15 (9.7)
Kuthiru/ Orkayama(local check)	1.9 (5.7)	2.0 (5.9)	2.0 (6.0)	1.8 (5.4)		1.25	----	1.58 (5.8)

Table 3: Mean grain yield of culture JO 583 in National Saline Alkaline Screening trials of AICRP

	Mean yield under different situations(Kg/ha)					
Name of culture/ National check	*IET No*	*Alkaline* [a]	*Alkaline Normal* [b]	*Coastal Saline* [c]	*Coastal Saline normal* [d]	*Inland saline* [e]
Culture JO 583	22609	2415	4929	3781	2468	2203
National check (CST 7-1)	-	2644	3538	3321	2466	1709

[a] Mean of 4 locations (Kanpur, Karnal, Karaikal, & Lucknow);
[b] Mean of 4 locations (Nawagam, Annamalainagar, Trichy, &Masodha)
[c] Mean of 3 locations (CRRI, Canning, & Machilipatnam)
[d] Mean of 3 locations (Chinsurah, Panvel, & Navasari)
[e] Mean of 2 locations (Karnal & Gangavati)

Figure : Mithila

at wet land condition of RARS Pattambi it is revealed that 'Mithila' is resistant to sheath blight and moderately resistant to brown spot and bacterial leaf blight (BLB), and resistant to leaf folder and gall midge, moderately resistant to whorl maggot, but susceptible to stem borer.

Salient characteristics of 'Mithila'

It is a medium duration variety (125-130days) having high grain and straw yield with high harvest index, and tolerant to low to medium salinity (4-6dS m^{-1}) as well as suitable for non saline flooded tract. It is suitable for saline Kaipad

tracts of North Kerala and saline Pokkali tracts of south Kerala. Unlike 'Kuthiru', the popular local cultivar of the ecosystem , it has intermediate plant stature (117cm) with strong and sturdy culm with wide angle orientation, and hence tolerant to lodging. Panicle is compact with 146 straw coloured grains panicle^{-1}. Healthy flag leaf and stay green index during reproductive stage shows its photosynthetic ability and efficient source sink relationship. As it is an organic variety developed for a naturally organic tract adopting the concepts and strategies of organic plant breeding, when we do cultivation in non-saline *Kaipad* tract, the management should be of organic mode and if farmers want to apply fertilizers, the recommendation may be of local cultivars.

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